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Petrogenesis of Kalisonggo tertiary lava, Girimulyo Kulonprogo, Yogyakarta based on mineralogy and geochemical analysis

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Abstract. The andesite lava that exposed in Kalisonggo, Girimulyo, Kulonprogo, Yogyakarta is the product of Kulonprogo Volcano activity. Kulonprogo Volcano is an ancient volcano that has three eruption centers. This study was conducted to determine the petrogenesis of Kalisonggo lava including sources, tectonic setting and other processes that controlled the formation of the lava. The methods used in this research are petrographic analysis (6 rock samples) and geochemical analysis (major oxides and trace elements) by XRF. Petrographic analysis shows that in general, all samples are composed of plagioclase, clinopyroxene, orthopyroxene, opaque mineral, and glass. Hornblende occurred in three samples from the south area only and no hornblende found in the sample from north area. The rocks have porphyritic, ophitic, glomeroporphyritic texture, and some plagioclase zoning. The XRF geochemical analysis result show that the rocks composition are andesitic-basaltic andesite. From SiO₂ vs K₂O + Na₂O diagrams and Co vs Th diagrams, the rocks is interpreted as product of Gajah volcano eruption. This product characterized by calc-alkaline magma series. The magma affinity indicates that the magma generated in subduction zone or island arc.

[Keyword: Kalisonggo, Petrography, Geochemistry, Andesite lavas, Island arc]

1. Introduction

Most of Kulonprogo region was formed geologically by ancient magmatic-volcano activity, consist of three andesite-dacite intrusion body. (Rahardjo, 1977). The research was conducted in Kalisonggo area, which located at eastern part of Kulonprogo Mountains, where the lava outcrops as part of Old Andesite Formation are exposed. (Fig. 1). The aims of the study are to determine the lithology variation of the lavas, to determine physical, mineralogy, and chemical characteristics of the lavas; and to understand magmatic affinity, differentiation processes and tectonic setting that controlled the magmatism related to the lava formation.



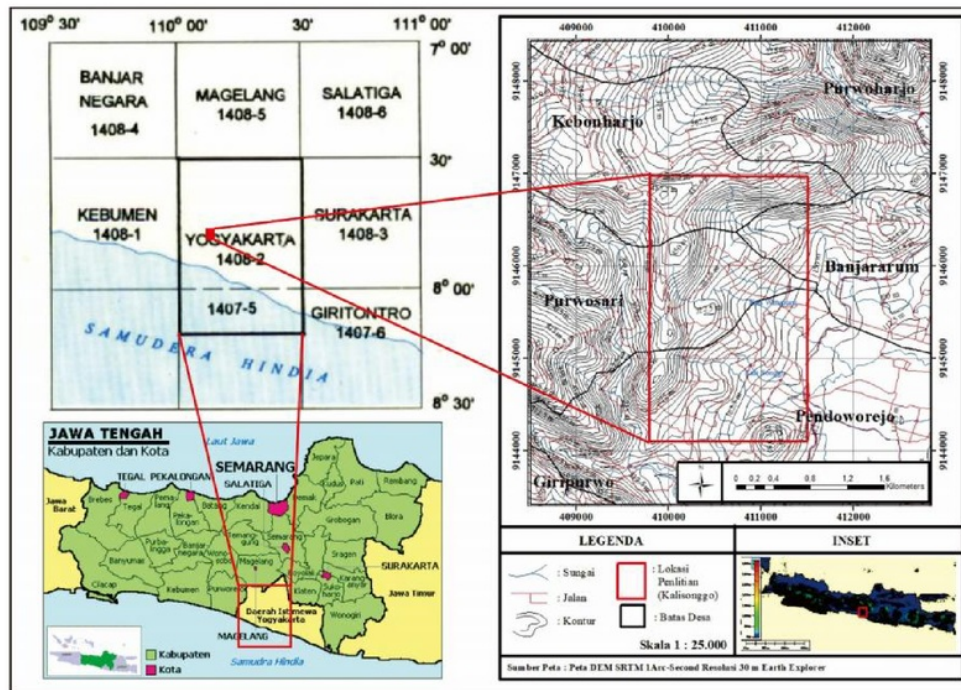


Figure 1. Location Map of Kalisonggo Area

2. Regional Geology

The research area located in Kalisonggo, Girimulyo Subdistric, Kulonprogo Regency, Yogyakarta. Physiographically, Kulonprogo is part of Southern Central Java Zone, known as Jonggrangan Plateau (Van Bemmelen, 1949). This zone resulted by uplift that formed a large dome. The elongated dome extend about 30 km on the North-South direction, around 20 km wide. The dome well known as Oblong Dome.

Stratigraphy of Kulonprogo area consist of four formation, from the oldest: Nanggulan Formation, Old Andesite Formation (Kebo Butak Fm.), Jonggrangan Formation, Sentolo Formation and Quaternary deposit.

Nanggulan Formation consist of sandstone, lignite, sandy marl and claystone with limonite concret¹³, limestone and tuff, foraminifera and molusc rich. The thickness of this formation about 300 m. Based on planktonic foraminifers, the age of this formation is Middle Eocene-Upper Oligocene Hartono (1969).

Old Andesite Formation (OAF) consist of andesite breccia, lapili tuff, tuff, lapili breccia, agglomerate, lava and volcanoclastic sandstone¹⁴. OAF unconformly depositd above Nanggulan Formation, with the thickness about 600 m, and the age of this formation is Oligocene – Miocene.

Jonggrangan Formation consist of tuff, marl, breccia, claystone with lignite, bioherm limestone and layered limestone in the upper part. The thickness of this formation about 2540 m, unconform above OAF and interfingering with Sentolo Formation. Based on biostratigraphy, Jonggrangan Formation age is Miocene. Sentolo Formation consist of tuffaceous marl in the lower part and marly sandstone and limestone in the upper part. It has thickness around 950 m, with geological age Lower Miocene - Pleistocene.

Quaternary deposit are formed along fluvial and coastal plain, consist of Alluvial and Colluvial deposit (gravel, sand, silt, clay and poorly sorted debris deposit), Sand dune deposit and Merapi Volcanic Deposit.

3. Methods and Sample Location

The methods used in this research are field mapping, rock sampling, petrographic analysis (6 samples), and geochemical analysis (X-Ray Fluorescence). Petrographic analysis used to determine rock texture and mineral composition, to interpret the magmatic differentiation process during the crystallization. Geochemical analysis

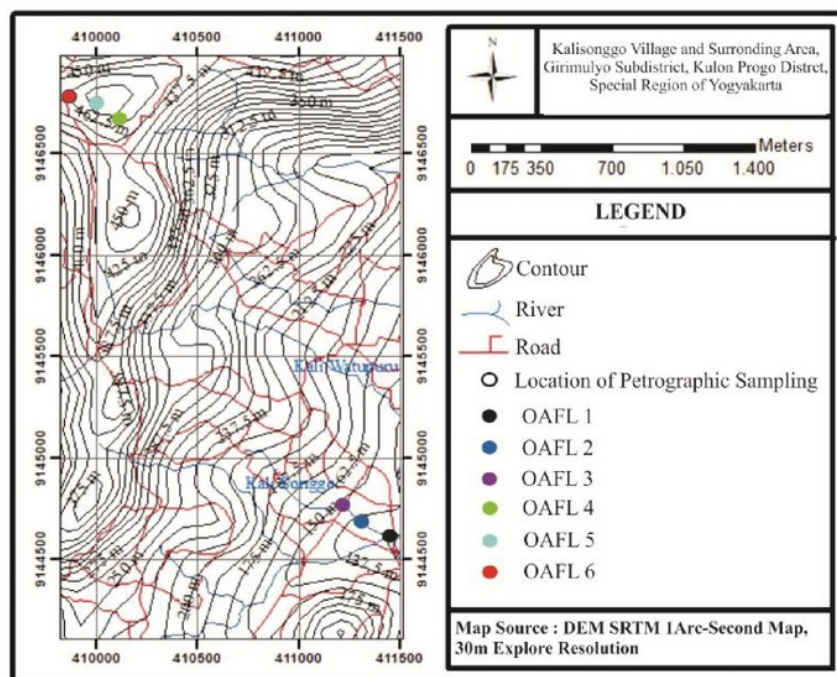


Figure 2. Sampling Location Map

4. Results and Discussion

4.1. Physical-optical properties of lava

Lava outcrops are exposed at two areas: southeast and northwest part of the research area. Physical properties of the lava outcrops are dark grey-black colour, fresh, sheeting joints (fig. 3- left), vesicular and autobrecciation (fig. 3- right).



Figure 3. sheeting joints (left), autobreccia (right). Kalisonggo lava

There are six petrographic samples, three samples from the southeast part (OAFL 1, OAFL 2 and OAFL 3) and three samples from northwest part (OAFL 4, OAFL5 dan OAFL 6). Based on texture and mineralogy, there are similarities and differences of the two sample groups. Major minerals of all samples are plagioclase (andesine and oligoclase) and clinopyroxene, but the pyroxene from the southeast samples are more abundant, and take part as groundmass. Northwest sample's pyroxenes occur as phenocrist and are associated with hornblendes, which are not found in southwest samples. (Table 1).

Table 1. Petrographic analysis resume

Code	Coordinat (UTM)	Mineral composition (%)					Specific textures				Rocks name
		Plg	Cpx	Opx	Hbl	Opq	Z	I	P	G	
OAFL-1	411451/9144617	60	35	-	-	5	V	V	-	-	Andesite
OAFL-2	411313/9144692	63	30	-	-	7	V	V	V	-	
OAFL-3	411218/9144765	65	28	-	-	7	V	V	V	-	
OAFL-4	410011/9146750	50	15	10	15	10	V	-	V	V	
OAFL-5	410113/9146667	45	25	10	12	8	V	-	V	V	
OAFL-6	409877/9146778	50	30	5	5	10	V	-	V	V	

Exp: Plg = plagioclase; Cpx = clinopyroxene; Opx = Orthopyroxene; Hbl = Hornblende; Opq = MineralOpak; Z = Zoning; I = Intergranular; P = Poikilitic; G = Glomeroporphyritic.

Specific textures that identified are zoning, intergranular, poikilitic dan glomeroporphyritic. Zoning are radial albite twinning of plagioclase, which developed by Ca-Na gradual composition change during crystal growth. The type of zoning being observed are oscillatory zoning (Fig. 4.A). Intergranular characterized by pyroxene minerals surrounded by elongated prismatic plagioclase (Fig 4.B). Intergranular texture is a result of plagioclase and pyroxene crystal growth at the same stage and relatively at the same temperature.

Glomeroporphyritic texture appear as intergrowth of plagioclase and pyroxene as phenocrist surrounded by finer groundmass. (Fig. 4.C). This type of texture formed by *symneusis*; crystal accumulation by surface tension. Poikilitic texture is spotted pyroxene enclosed by large plagioclase (Fig 4.D), it represent the different crystal growth pattern between plagioclase and pyroxene, where pyroxene crystal stop grow as plagioclase keep grow continually.

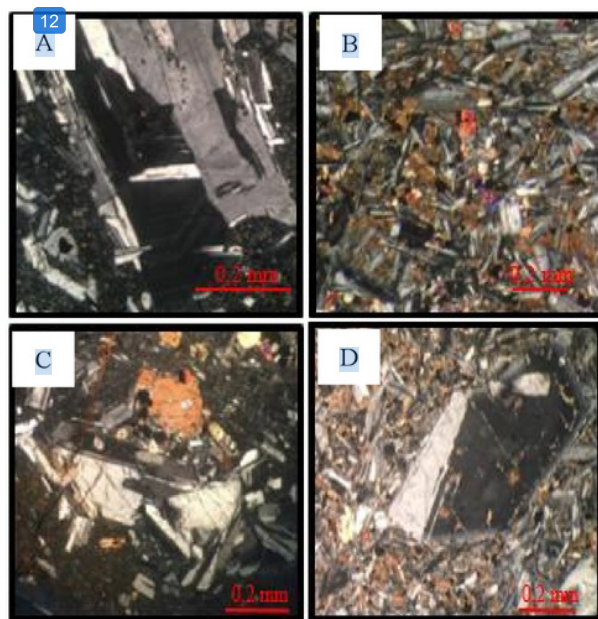


Figure 4. specific texture of rock samples: A) oscillatory zoning, B) intergranular, C) glomeroporphyritic, D) poikilitic

4.2. Geochemical analysis

6 rock samples had analyzed, the same samples analyzed by petrographic method: OAFL 1, OAFL 2, OAFL 3, OAFL 4, OAFL 5, dan OAFL 6. The result of XRF analysis are major oxides (Table 2) and trace elements concentration (Table 3).

Table 2. Major elements composition (weight %).

Kode Sampel	Na ₂ O	MgO	Al ₂ O ₃	SiO ₂	P ₂ O ₅	K ₂ O	CaO	TiO ₂	Fe ₂ O ₃
OAFL 1	3,74	5,828	18,33	55,43	0,527	1,1	6,83	1,15	9,595
OAFL 2	4,02	6,246	19,01	55,17	0,497	1,03	6,4	0,96	9,273
OAFL 3	3,4	8,247	16,82	55,07	0,457	1,04	6,55	0,95	10,11
OAFL 4	4,72	2,835	19,89	59,99	0,472	1,45	6,15	0,62	6,457
OAFL 5	4,75	2,687	20,1	60,48	0,432	1,47	6,11	0,59	6,015
OAFL 6	5,2	2,322	20,69	59,51	0,311	1,43	5,85	0,59	6,583

Table 3. Trace elements concentration (ppm)

Kode Sampel	Th	Nb	Ta	Sr	Zr	Hf	Y	Co
OAFL1	4,7	3,2856	0,8189	272,366	197,36	5,4	36,5	16,28
OAFL2	1,7	2,6564	0,8189	246,068	167,09	6,2	32,7	13,606
OAFL3	3,3	3,8448	0,8189	276,763	228,53	7,8	35,7	14,471
OAFL4	4,7	4,9633	0,8189	289,532	651,24	14,5	59,4	16,044
OAFL5	5,3	3,0059	0,8189	305,175	505,77	15,7	53,1	19,111
OAFL6	5,1	4,1943	0,8189	275,326	1366,6	9	107,3	21,313

Based on SiO₂ concentration, sample from southeast part (OAFL 1,2,3) have lower concentration (near basaltic) than samples from northwest part (OAFL 4,5,6) around 55% compare to around 60%. Moreover, the MgO and Fe₂O₃ from southeast samples are higher than those of northwest samples: around 6-8% compare to around 2-3% MgO and 9-10% compare to 6% Fe₂O₃ (shaded data), those confirm that southeast samples (OAFL 1,2,3) more basaltic than northwest samples. The difference of SiO₂, MgO, and Fe₂O₃ composition of the samples is evidence that the lava exposed at southeast genetically different from those exposed at the northwest side, or they were generated from different magma source both in term of time and/or place.

Volcanic rocks type determination using several discriminant/classification diagrams (fig. 5): A. SiO₂ vs Na₂O + K₂O (Le Bas dkk., 1986), B. SiO₂ vs Na₂O + K₂O (After Cox Bell Pank, 1979), C. SiO₂ vs K₂O (After Gill, 1981), D. SiO₂ vs K₂O (Ewart, 1982) serta E. Co vs Th (Hastie dkk., 2007). Based on data plot on those 5 diagrams, all samples consistently show similar pattern, where samples OAFL 1,2,3 classified as basaltic andesite, and OAFL 4,5,6 classified as andesite.

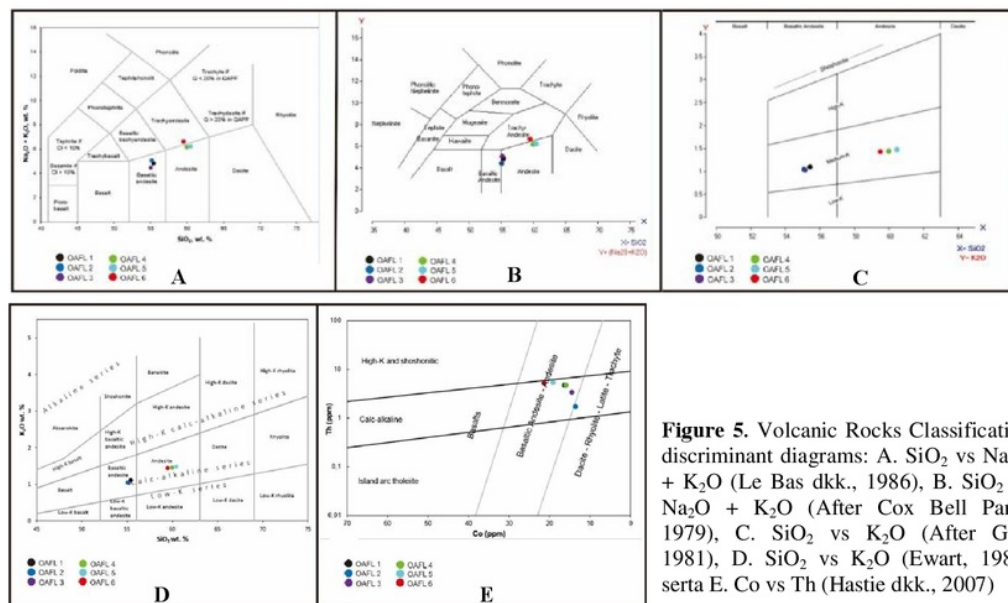


Figure 5. Volcanic Rocks Classification discriminant diagrams: A. SiO_2 vs $\text{Na}_2\text{O} + \text{K}_2\text{O}$ (Le Bas dkk., 1986), B. SiO_2 vs $\text{Na}_2\text{O} + \text{K}_2\text{O}$ (After Cox Bell Pank, 1979), C. SiO_2 vs K_2O (After Gill, 1981), D. SiO_2 vs K_2O (Ewart, 1982) serta E. Co vs Th (Hastie dkk., 2007)

Based on SiO_2 -($\text{Na}_2\text{O} + \text{K}_2\text{O}$) ratio (fig. 6) all samples classified in sub alkaline magmatic affinity or calc alkaline. Calc alkaline series magma could only generated in convergent plate margin setting (Wilson, 1989), thus confirmed that the tectonic setting of Kalisonggo lava magma generation is subduction zone.

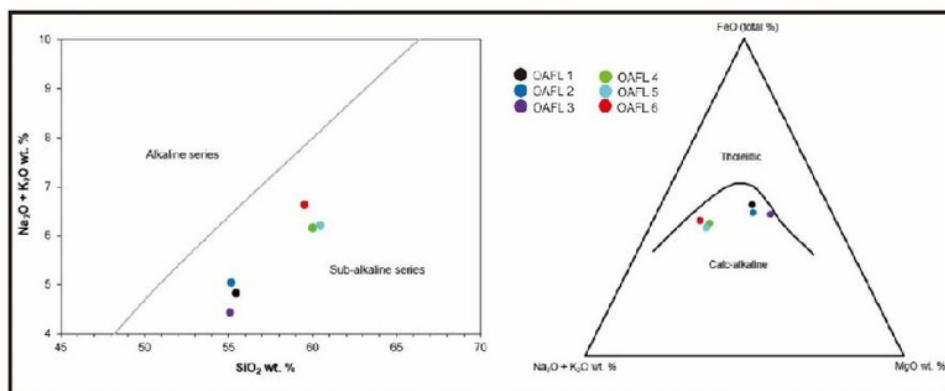


Figure 6. Binary discriminant chart SiO_2 vs $\text{Na}_2\text{O} + \text{K}_2\text{O}$ (left) and $\text{FeO}_{\text{Total}}$ vs $\text{Na}_2\text{O} + \text{K}_2\text{O}$ vs MgO (right) used to determine magmatic affinity (Irvine dan Baragar, 1971)

Tectonic setting determination using TiO_2 - MnO - P_2O_5 diagram, all samples plotted into same area island arc calc alkaline basalt. Determination using ternary $\text{FeO}_{\text{Total}}$, MgO and Al_2O_3 all samples classified into island arc and active continental margin. Otherwise, data plot using trace elements ternary $\text{Hf}/3$ vs Th vs Ta ; $\text{Hf}/3$, Th , $\text{Nb}/16$; and $\text{Zr}/117$, Th , $\text{Nb}/16$ confirm that the lava derived from magma source which generated in island arc setting (Fig. 7.A) with calc alkaline basalt type magma series (CAB) (Fig. 7.B).

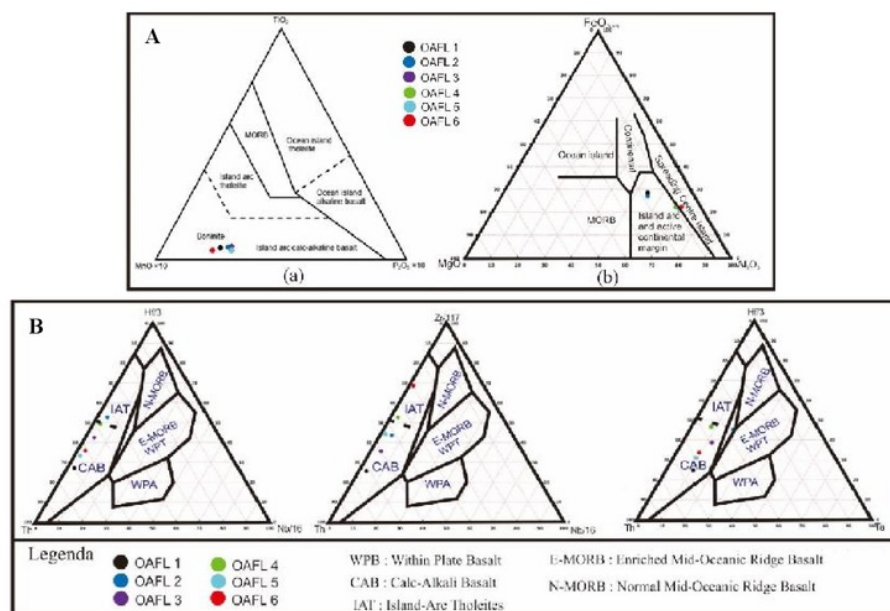


Figure 7. Tectonic setting determination: A. a) FeO vs $\text{MnO} + \text{P}_2\text{O}_5$ (Mullen, 1983) A.b) FeO_{Tot} vs $\text{Na}_2\text{O} + \text{K}_2\text{O}$ vs MgO (Pearce dkk, 1971) and B. $\text{Hf}/3$ vs Th vs Ta ; $\text{Hf}/3$, Th , $\text{Nb}/16$, dan $\text{Zr}/117$, Th , $\text{Nb}/16$ (Wood, 1980)

5. Conclusion

Kalisonggo Lava are classified into andesite (Streckeisen, 1967). Specific texture that identified are *intergranular*, *zoning*, *glomeroporphyritic* and *poikilitic*. Based on geochemical character, there are two type of lava/magma source, basaltic andesite of southeast outcrop and andesite of northwest outcrop. Magmatic affinity classified into calc-alkali, and the magma formed in Island Arc calc-alkaline basalt tectonic setting.

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